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## THE MEASUREMENT OF OPTICAL UNEVENNESS

Project 3270

Report One

A Progress Report

to

MEMBERS OF THE INSTITUTE OF PAPER CHEMISTRY

March 5, 1976

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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# THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

## THE MEASUREMENT OF OPTICAL UNEVENNESS

### SUMMARY

One of the most important characteristics of printing paper is that it should be free of mottle or reflectance unevenness and that it print without unevenness, particularly where uniform tones are required. Mottle of paper may be due to various causes such as the imperfect masking of the color of a darker base stock by a coating of nonuniform thickness or by calendar blackening in local areas of high mass. Prints, even on paper of uniform reflectance, may be uneven due to surface roughness or nonuniform absorptivity which interfere with uniform transfer and acceptance of ink. Unevenness of either type is usually judged visually because standard instruments measure averages of areas too large for detection of the troublesome variation.

An instrument for objective measurement of optical unevenness was first described by the Institute in 1969. It differs from previous devices which had been proposed in that it is a comparison instrument, which continuously compares the reflectance of small areas along a scanning path with the simultaneously sensed local average reflectance of the surrounding area. This greatly improves the sensitivity because the instrument need operate only over the range of the reflectance variation rather than record the full range of the reflectance. Furthermore, the instrument imitates the eye to the extent that it is extremely sensitive to slight variation in reflectance of small areas from the local average but relatively insensitive to variation of similar magnitude when it occurs gradually over greater distances. In spite of these important advantages, the instrument has not been used extensively because of its very limited scanning speed.

A new instrument which retains the advantages of the former device at practical scanning speeds is now under development. This report describes the changes which have been made and includes the results of preliminary evaluation experiments which indicate that increased speed has been achieved without sacrifice in sensitivity. Changes in the specimen advance mechanism and in the data logging facilities are now being made in preparation for studies relating the instrumental values to visually judged unevenness.

## INTRODUCTION

The optical properties such as brightness, opacity, color, and gloss are generally accepted as being of great importance in printing papers. However, it is well known that the eye is not particularly sensitive to small changes in these properties from one paper to another unless a side-by-side comparison is made. However, the eye is sensitive to small changes in optical properties particularly when the changes occur abruptly over small distances within a sheet of paper. One might suppose, therefore, that unevenness of the optical properties within the sheet would be more important than the exact level of these properties. In spite of this, optical properties are usually determined with instruments of large aperture which provide average readings over the area tested but do not indicate the small area evenness of these properties.

Printed papers frequently exhibit an unevenness which may be referred to as "rough printing." It may be due in part to optical unevenness of the paper itself but is usually due to uneven topography, mass, or absorbance of the paper which prevents the faithful transfer of image elements of the printing plate. The ability to accept uniform printed tones without objectionable unevenness is one of the most important attributes of high quality printing papers. Most paper manufacturers prepare quality control prints under conditions chosen to simulate or exaggerate conditions to be used in the commercial printing operations. Such prints are visually graded, in large part according to the evenness of the printed tones, as a means of insuring that paper of good printability is being produced.

An instrument which can objectively grade the optical unevenness of both papers and prints made under controlled printing conditions, in a manner that agrees with visual evaluation, would be useful, both in quality control and in the

development of new printing grades. An instrument for measurement of optical unevenness, built at The Institute of Paper Chemistry (1), has been shown to be extremely sensitive to small variations in reflectance but has been too slow for practical application. The present project endeavors to overcome these instrument limitations and to study the relationship between instrumental and visual assessments so that useful objective unevenness parameters can be selected. This first report discusses the various aspects of unevenness measurement which have been considered in the development of a new instrument. It also describes the instrument and presents limited preliminary measurements as examples of the capabilities of the instrument.

#### OBJECTIVE

The objective of this project is to provide manufacturers of printing papers with a means of objectively determining the optical unevenness of papers and prints in a way that will correlate with subjective evaluation.



## DISCUSSION

### TYPES OF UNEVENNESS INSTRUMENTS

The instruments for measuring optical unevenness have generally been scanning microdensitometers and microreflectometers which provide profiles of the reflection density or reflectance. The original Institute instrument (1) departed from previous instruments in that it continuously compared the reflectance of a small spot with the simultaneously sensed reflectance of the larger area surrounding the small spot. This design was adopted because it is known that the eye is extremely sensitive to the extent to which a small spot differs from its surroundings but is insensitive to like differences in reflectance when they occur gradually. The instrument was therefore designed to imitate the eye in this respect. Another advantage of the twin aperture design is the great increase in sensitivity which is possible with a comparison instrument over one which must respond to the full reflectance range. At the time that the Institute instrument was first described it was unique. More recently, Larsson et al. (2) has described a twin aperture densitometer which operates in a similar manner. Ullman and Qvarnstrom (3) have developed a single aperture instrument which simultaneously provides the average reflectance and variation in reflectance by the  $\text{dc}$  and  $\text{ac}$  components of its electrical output.

Experience with the twin aperture design has been very encouraging. The only difficulty with the instrument has been the very slow scanning speed which has restricted the utility of the instrument and prevented full evaluation of its correlation with subjective measurements. Therefore the twin aperture design has been adopted for the new instrument.

## TYPES OF OPTICAL UNEVENNESS

Studies of the unevenness of prints prior to 1968 have been reviewed by Poulter (4) and by Karttunen (5). Unevenness has been classified as "speckle" and "mottle." Speckle is the high contrast unevenness due to irregularity in the relative areas of inked and uninked paper. Speckle would include unevenness due to missing dots in gravure prints, the nonuniform dot area of halftone letterpress prints, and unprinted depressions in solid prints. Mottle is low contrast unevenness such as may be due to small scale variation in the thickness of coating on a darker base stock. In prints it may be due to the uneven thickness or finish of the ink film caused either by uneven absorptivity of the paper or by the manner in which the ink film is split during the printing operation.

From the standpoint of visual observation, fine speckle unevenness may also be considered to be a low contrast unevenness since it is not resolved by the eye. The situation is analogous to that of a picture of delicate tone gradation which may be produced in either continuous tone or by halftone dots upon a white substrate. The individual dots are not resolved by the eye but the integrated reflectance of areas containing dots and white background are perceived as an intermediate gray tone. Therefore there is no reason why an instrument which integrates over the proper area should not be used to objectively measure both fine speckle and mottle in a way that will correlate with visual evaluation.

## APERTURE SIZE AND SHAPE

Scanning devices which have been used to measure unevenness have used effective apertures ranging from 0.015 to 3.0 mm. However the finer apertures have been used in an attempt to resolve the speckle pattern and determine the distribution of inked and uninked paper. Some indication of the size of aperture

that will integrate the fine speckle and provide a response similar to that of the eye may be derived from the work of Bauer (6) who has developed a theory based on an elementary cell of visibility. He has determined the diameter of the cell at a viewing distance of 20 cm to be 175  $\mu\text{m}$ . Most printed matter is viewed from a distance of at least 25 cm so the effective diameter would be correspondingly increased. These figures are at least roughly in accordance with the observation that most people are unaware of a screen pattern in printed material at 100 lines per inch. The distance between dot centers in such a print is 254  $\mu\text{m}$ . This figure should be considered a minimum estimate of the required aperture. It is probable that a paper or print would not appear objectionably uneven if there were no variations when the reflectance is integrated over aperture areas several times that of a unit screen element. The common "rosette" moire of color prints formed by three screen tints printed at 30 degrees separation is detectable by the eye but is not usually considered to be objectionable. It contains concentric circles of dots arranged at diameters 1.41 and 3.16 times the screen ruling.

The shape of the aperture is not critical for scanning unprinted papers or solid prints. However a square aperture has an advantage where syzygetic\* scanning is desired because the whole sample can be covered without overlap or missing any sample area. However the shape is of greater importance for scanning halftone prints because of the need to suppress the pattern of the dots. Diehl (7) was apparently first to report a scanning device to measure the integrated reflectance from the unit cell of a halftone print. This requires a square aperture the exact size of the unit cell which is precisely oriented with the screen direction. The scanning direction is unimportant. Nordman and Makkonen (8)

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\*The term syzygetic indicates that values are determined for each adjacent aperture area.

have also used square apertures to scan halftones. It is, of course, possible to use larger square apertures. A square with side  $n$  times the screen ruling distance will include a constant integrated dot area equivalent to 1, 4, 9, ...  $n^2$  individual dots. It is also possible to use a square oriented along the diagonal of the screen pattern. In this case a square  $m$  times the diagonal distance will include a constant integrated dot area equivalent to 2, 8, 18, ...  $2m^2$  individual dots. Use of the larger apertures increases the requirement for sensitivity because the effect of a small improperly printed area is integrated over a larger area.

In view of the above considerations, a square aperture of continuously adjustable size has been specified for the new unevenness instrument. Aperture plates with 1/8 and 1/16 inch diameter circular openings, corresponding to effective apertures at the specimen plane of 0.64 and 0.32 mm, respectively, have also been provided for alternative use.

#### RELATIONSHIP OF OBJECTIVE MEASUREMENT TO VISUAL ASSESSMENT

Whenever prints are produced to be viewed by people, rather than by machines, visual assessment must be the final authority concerning printing quality. Objective measures of quality characteristics will be useful to the extent that they quickly and reproducibly predict the quality rating which a judging panel would assign when judging the same characteristic. Therefore, it is essential that an instrument for objective measurement of unevenness imitate the observer in the way it examines the specimen and in the characteristics it detects.

An uninstructed observer who is asked to examine a printed or unprinted sheet for mottle may look at it with several viewing geometries because gloss mottle is most apparent at the glare angle and other types of unevenness are best detected at other angles. His assessment would be a composite of the impressions formed

under the varying conditions. It is not feasible to do this instrumentally. However, we may logically assume that the detrimental unevenness is that which is apparent under the viewing conditions which apply in the intended use of the printed product. Readers avoid the glare angle so the judging panel should be restricted to a viewing geometry, such as  $45^{\circ}$ - $0^{\circ}$  for example, at which the effect of gloss mottle is not unreasonably exaggerated. With the subjective viewing geometry established, it is relatively easy to approximate it instrumentally. In the present work  $45^{\circ}$ - $0^{\circ}$  has been adopted as a reasonable standard condition, representative of average end-use viewing conditions. This geometry is used in the instrument and will also be used in the subjective ranking experiments needed to correlate objective and visual results.

It should be recognized that a paper or print can be uneven in many ways. It could be uneven in color. However, because of the three dimensional nature of color characteristics, color unevenness would be difficult to determine or to express. It is believed that most unevenness is detectable as variation in the single dimension of lightness. Therefore, the spectral sensitivity of the instrument should correspond to that of the eye - it should be that of the CIE lightness or  $\bar{Y}$  function\*. Previous workers have usually not indicated the spectral sensitivity of their instruments. This may be because they have been concerned primarily with black ink on white paper where wide ranges in spectral sensitivity are permissible. However, in the interest of broad utility it was decided to adjust the spectral sensitivity of the new instrument to the  $\bar{Y}$  function.

It is desirable that the lightness variation detected by the instrument be represented on a scale in which equal increments correspond to visually equal

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\*In this report the symbol  $\bar{Y}$  is used to denote the reflectance with the instrument adjusted to this CIE  $\bar{Y}$  function. The symbol  $\bar{R}$  is used for reflectance of unknown or indefinite spectral distribution.

steps of lightness regardless of the lightness level. Neither the CIE lightness  $\underline{Y}$  nor any other reflectance has this characteristic. This shortcoming can be ignored if all samples to be compared are of the same average lightness, but it becomes important as the range of sample lightness levels to be compared increases. The proper scale of uniform lightness difference is the Munsell Value,  $\underline{V}$ , in which 0.0 is a perfect black and 10.0 is a perfect white. Munsell Value is a psychophysical scale which was developed subjectively. It can be related to  $\underline{Y}$  by interpolation on charts or by the Equation (9),

$$Y = (1.2219 V - 0.2311 V^2 + 0.23951 V^3 - 0.02100 V^4 + 0.0008404 V^5)/1.0256$$

which is rather complicated for routine use.

Previous workers (5) have usually expressed variation as the standard deviation of reflectance,  $\sigma_{\underline{R}}$ ; the coefficient of variation of reflectance,  $\sigma_{\underline{R}}/\bar{\underline{R}}$ , where  $\bar{\underline{R}}$  is the average reflectance; the standard deviation in reflection density,  $\sigma_{\underline{D}}$ ; or the average syzygetic density difference. Nordman and Makkonen (8) have indicated that a more uniform scale is obtained by multiplying the coefficient of variation by the logarithm of the average reflectance,  $(\sigma_{\underline{R}}/\bar{\underline{R}}) \log \bar{\underline{R}}$ .

The visual uniformity of lightness scales can be evaluated by differentiating with respect to  $\underline{V}$  in order to provide the scale increment per unit increment in  $\underline{V}$ . Figure 1 contains plots of  $d\underline{Y}/d\underline{V}$ ,  $(1/\bar{\underline{Y}}) (d\underline{Y}/d\underline{V})$ ,  $(\log \bar{\underline{Y}}/\bar{\underline{Y}}) (d\bar{\underline{Y}}/d\underline{V})$  and  $d\underline{D}/d\underline{V}$  vs.  $\bar{\underline{V}}$ . It is evident that Nordman's scale is the most uniform of this group although it deviates wildly at very low lightness levels.

Pobboravsky, Pearson and Yule (10) have used a darkness scale based on the cube root equation of Wyszecki (11). The darkness,  $\underline{F}$ , is given by the equation,

$$F = 117 - 25 Y^{1/3}.$$

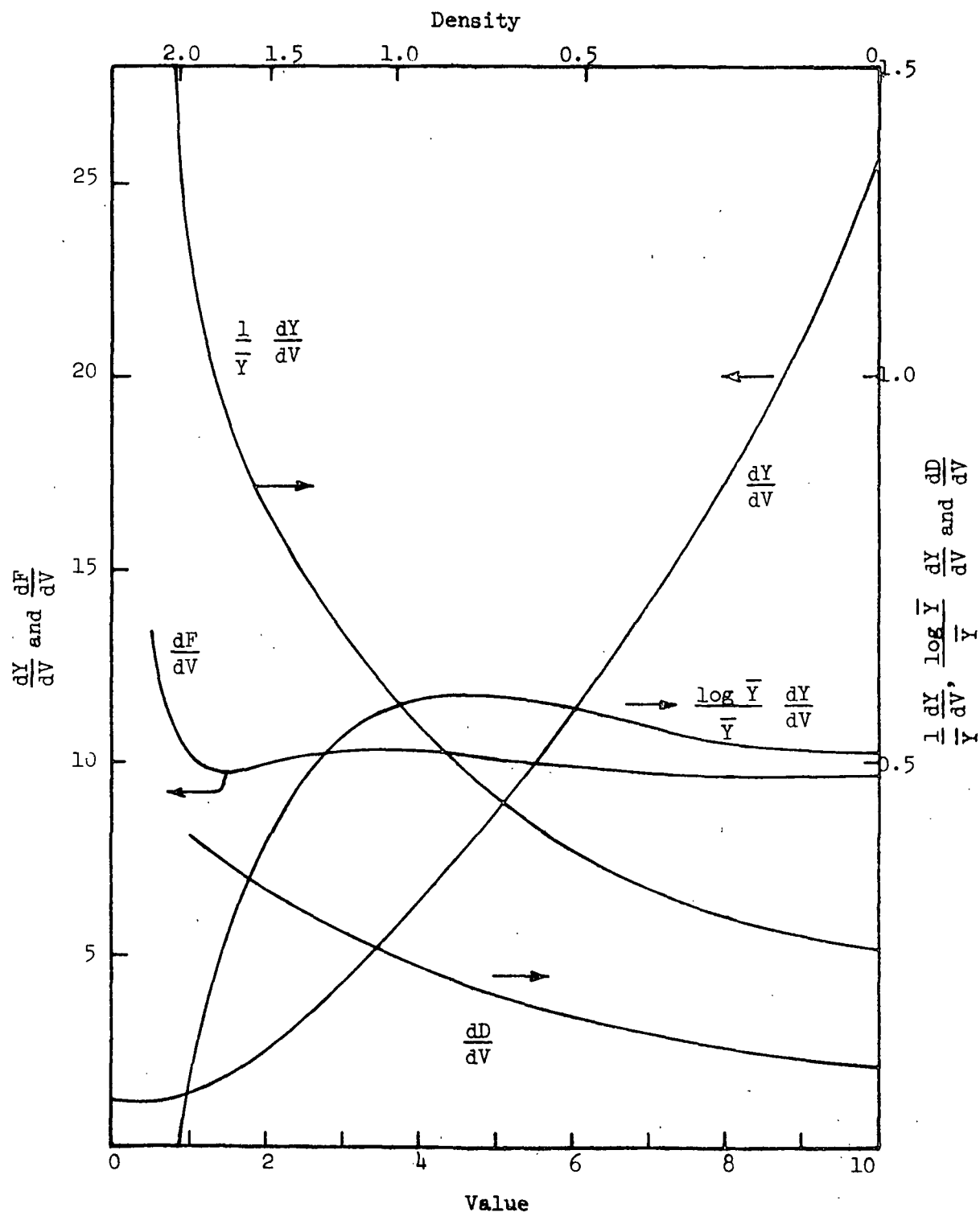


Figure 1. Plot Showing the Increment per Unit of Munsell Value for Various Unevenness Scales as a Function of Value

$\underline{F}$  is very nearly linear with  $\underline{V}$  when  $\underline{Y}$  is not less than 1%. For lower values of  $\underline{Y}$  the equation,  $F = 100 - 8 Y$ , is recommended.  $\underline{F}$  has not been used to express unevenness. However, the plot of  $d\underline{F}/d\underline{V}$ , which is included in Fig. 1, indicates that it would be superior to the other scales which have been considered. The use of darkness rather than lightness is probably more appropriate for the graphic arts. However, as a measure of unevenness, the nearly uniform lightness,  $\underline{W}$ , provided by the Wyszecki equation,  $W = 25 Y^{1/3} - 17$ , would serve equally as well.

Based on the consideration of the above scales it was decided to use the  $\underline{Y}$  reflectance as the instrument scale. Although this is the least uniform of the scales considered, it is the most easily converted to any of the others during calculation of an unevenness parameter. However, it is necessary that the average  $\underline{Y}$ ,  $\overline{Y}$ , be known. The original unevenness instrument provided only the ratio of the small spot reflectance to the local average without indicating either individual reflectance. The average value, if needed, had to be determined on another instrument. Consequently, it was decided that the new instrument provide the option of recording the small aperture lightness,  $\underline{Y}_s$ , the large aperture lightness,  $\underline{Y}_l$ , or the difference,  $\underline{Y}_s - \underline{Y}_l$ . The ratio, if needed, can be calculated since

$$(\underline{Y}_s - \underline{Y}_l)/\underline{Y}_l = (\underline{Y}_s/\underline{Y}_l) - 1.$$

Therefore, the instrument will provide all the information needed to calculate the unevenness according to any of the scales which have been discussed. In addition, the capability of reading the lightness directly will permit calibration against standards of known lightness.

It must be recognized that unevenness, even when limited to lightness variation, can occur in various ways. Most of the studies correlating objective and subjective unevenness have considered only the amplitude of the variation. The



unevenness parameters discussed above, which contain the standard deviation of the reflectance, do not include any measure of the sample distance (or frequency) over which these variations occur. Blokhuis and his coworkers (12) have analyzed their syzygetic density difference data in a manner which provides frequency information but their purpose was correlation with objective measures of paper roughness rather than subjective unevenness. Sankey and Foss (13) used frequency as a means of relating print unevenness to formation irregularities such as wire mark. However there seems to have been no study of the effect of pattern periodicity upon subjective unevenness assessment. It may be expected that some factor involving the frequency of variation may need to be included with the amplitude information in order to secure agreement between objective and subjective evaluations over a wide range of sample types.

## DESIGN OF EQUIPMENT

### BASIC DESIGN

The basic feature of simultaneous detection and comparison of the small spot reflectance with the average reflectance of the larger surrounding area, which was employed in the original instrument (1), has been retained. The optical system is shown schematically in Fig. 2. The principle change required was the replacement of the photoconductive receptors which, because of their "memory," severely limited the scanning speed of the original instrument. Change to silicon photodiodes required other changes in electrical circuitry and in level of illumination. These and other changes are described in the following paragraphs.

### LIGHT DETECTION AND MEASUREMENT

Two silicon photodiodes (United Detector Technology PIN 10) are used to detect the light transmitted through the small and large apertures of the instrument. Signals from these cells are amplified in the two channel solid state amplifier shown in the schematic diagram of Fig. 3. One of the amplified signals is then inverted in polarity and mixed with the other signal to provide a difference signal which is further amplified. The output of the amplifier is recorded with an Esterline-Angus Speed Servo recorder which has a full scale response rate of 1/8 second. The recorder is by far the limiting component with respect to speed of response and can be replaced with other data logging equipment when this becomes desirable.

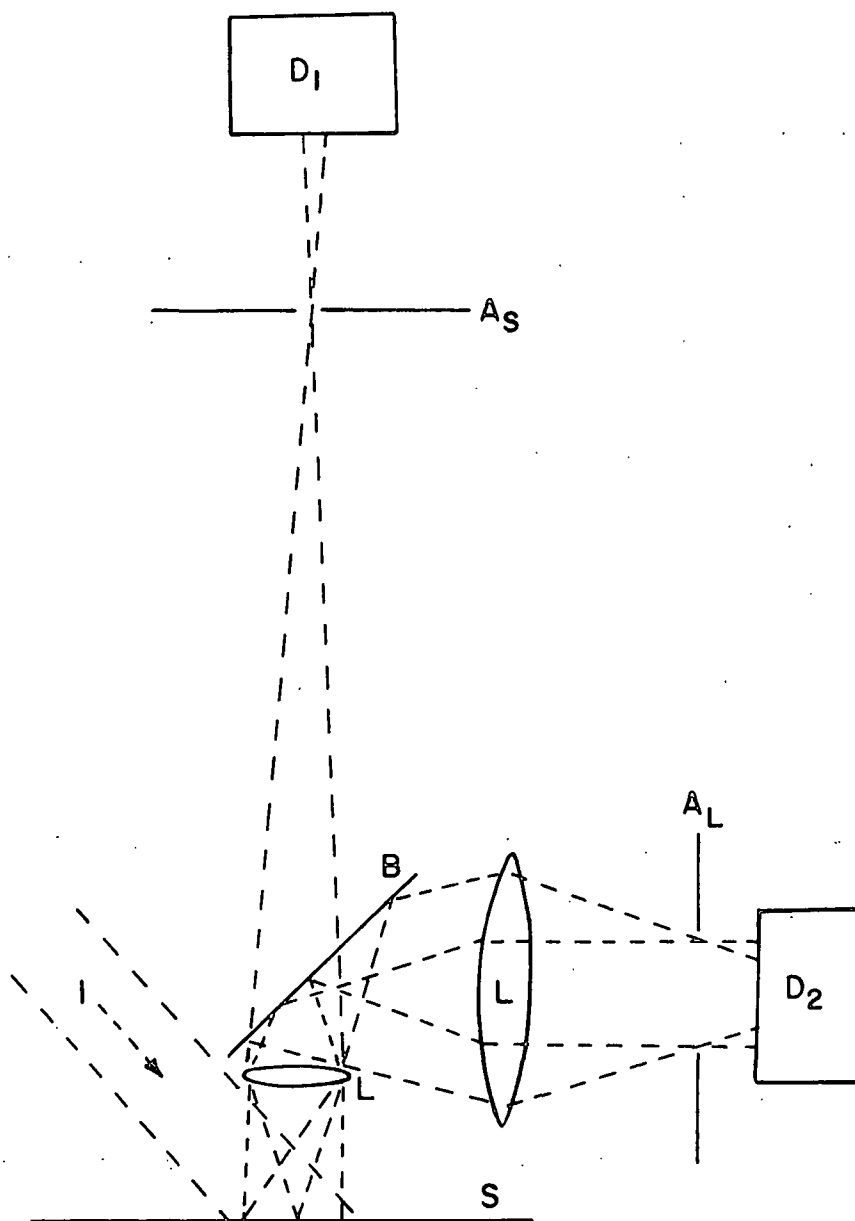


Figure 2. Schematic Diagram of the Optical System. I is the Incident Light Beam. Light Reflected by the Specimen, S, Passes Through the Lens, L, to the Clear Glass Beam Splitter, B. Light Transmitted by the Beam Splitter Which is Accepted by the Small Aperture, A<sub>S</sub>, is Detected by the Photoreceptor, D<sub>1</sub>. Light Reflected by the Beam Splitter and Accepted by the Large Aperture, A<sub>L</sub>, is Detected by the Photoreceptor, D<sub>2</sub>

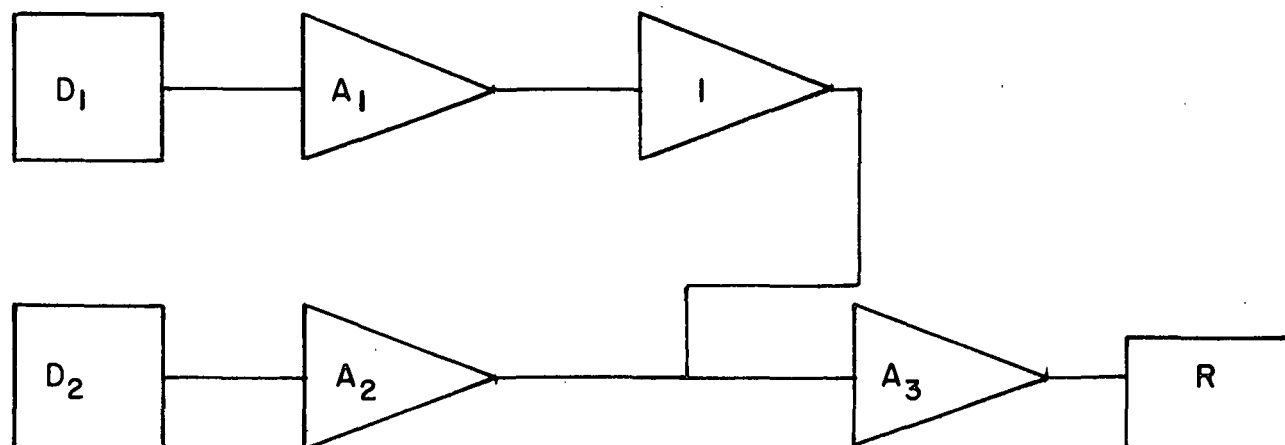


Figure 3. Schematic Diagram of the Amplifier System.  $D_1$  and  $D_2$  are the Detectors,  $A_1$  and  $A_2$  are the Amplifiers,  $I$  is the Signal Inverter,  $A_3$  is the Difference Amplifier, and  $R$  is the Recorder

The reflectance of either the small spot or the large spot can be recorded by switching off the other channel. This feature is also used to adjust the gain of each channel independently to correctly read the reflectance of standards of known reflectance. The zero difference is then set at the center of the recorder chart and the scale expanded as required by switching to a more sensitive recorder scale.

#### INCIDENT LIGHT SOURCE

The previous instrument employed a General Electric No. 1962 quartz-iodine lamp which was operated at 6 volts. This source did not provide adequate light for the silicon photodiodes. Therefore, the optical system shown schematically in Fig. 4 was constructed.

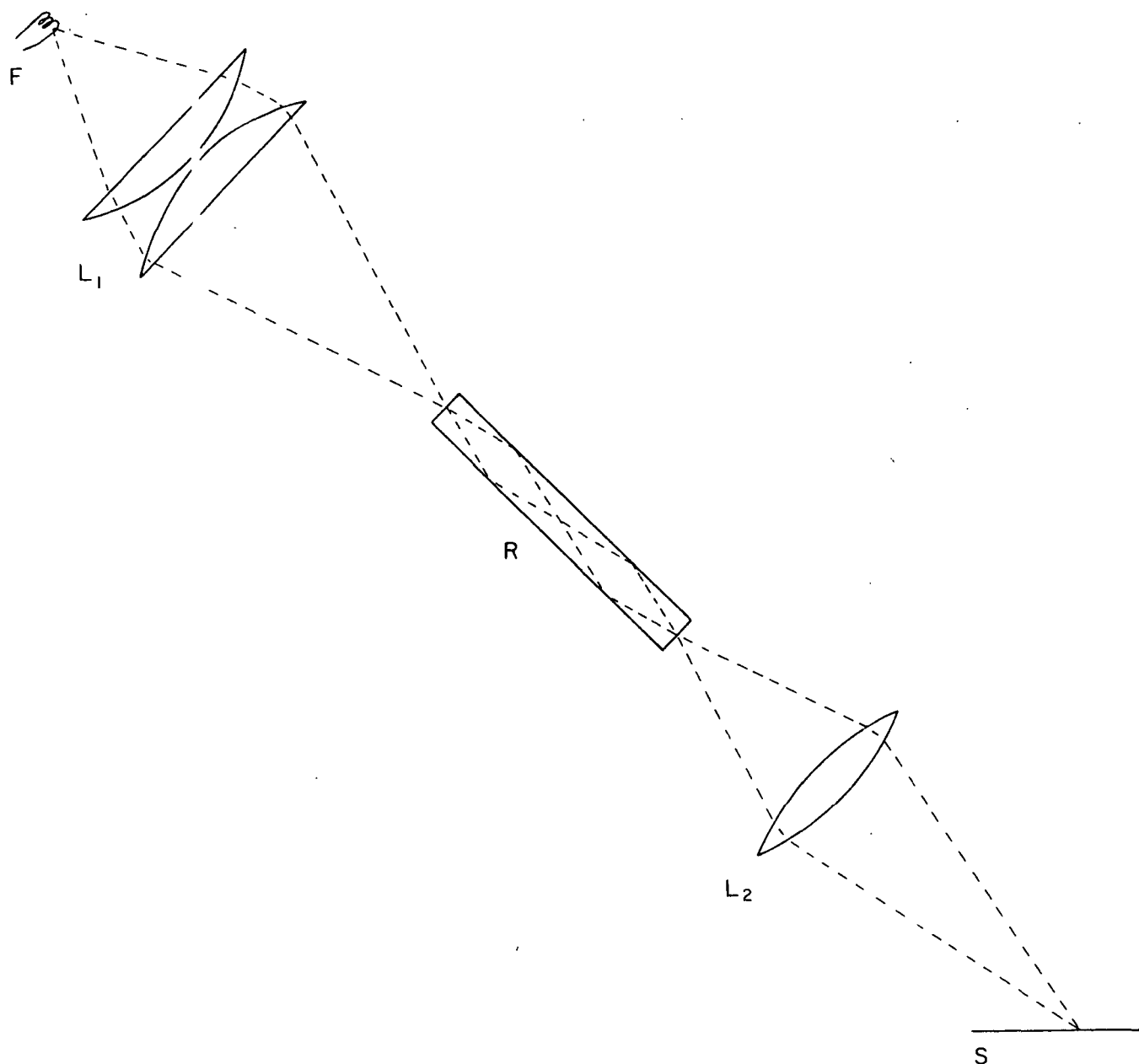


Figure 4. Schematic Diagram of the Incident Light Source. F is the Lamp Filament, L<sub>1</sub> and L<sub>2</sub> are Lenses, R is a Glass Rod Light Guide, and S is the Specimen

The entire filament of a Sylvania BCL Tungsten-Halogen 300 watt projection lamp is focussed by the condensing lens  $L_1$  on the end of a 9 mm solid glass rod which is aluminized on its cylindrical surface. Light issuing from the other end of the glass rod is focussed upon the specimen by the lens  $L_2$ . This permits utilization of substantially all of the light entering the rod from the whole filament to illuminate a restricted area of the specimen without having the image of the filament in focus at the specimen. It should be noted that the light is not collimated. The beam issuing from lens  $L_2$  has a bullseye pattern due to portions of the light which are subject to 0, 1, 2, etc., reflections within the rod. However, this pattern converges to form a uniform image of the exit end of the rod upon the specimen. There appears to be no disadvantage to using noncollimated light and there may be some advantage in that the effect of surface roughness upon the detected profiles is probably reduced. The lamp is operated at 108 volts ac using a voltage regulator. This should extend the life of the lamp considerably beyond the 1000 hours for which it is rated at 120 volts ac. The lamp house is cooled with a fan and in addition there is a 1/4 inch tempered heat absorbing glass plate between the lamp and the condensing lens.

The maximum sensitivity of the silicon photodiodes is in the near infra-red region. Therefore, filters are required in the light source to convert the overall instrument response to that of the CIE  $\bar{y}$  function. These filters are inserted in the light path at the exit end of the glass rod. The method of Van den Akker and Dearth (14) for calibration of filter colorimeters was used to select the proper combination of filters. The filters selected and the instrument response to the calibration filters provided by Dearth are shown in Table I.

TABLE I  
EVALUATION OF SPECTRAL RESPONSE

| Calibration<br>Filter | Response, %           |                    |       |
|-----------------------|-----------------------|--------------------|-------|
|                       | Required <sup>a</sup> | Found <sup>b</sup> | Error |
| R (brown)             | 60.4                  | 59.7               | -0.7  |
| V (blue)              | 68.3                  | 67.3               | -1.0  |
| W (blue)              | 25.8                  | 26.3               | +0.5  |
| X (red)               | 24.6                  | 25.4               | +0.8  |
| Y (red)               | 5.8                   | 7.2                | +1.4  |

<sup>a</sup>Response required for the CIE  $\bar{y}$  function.

<sup>b</sup>Response found with the following combination of filters in the incident beam:

LB-120 (Hoya) 55.5% transmission at 457 nm  
 C-500 (Hoya) 31.6% transmission at 650 nm  
 3-77 (Corning) 75% transmission at 550 nm  
 4-65 (Corning) 53% transmission at 457 nm  
 1/4-inch thick tempered heat absorbing glass plate.

#### APERTURES

Round apertures in which the openings are 1/16 and 1/8-inch in diameter are provided. Since the magnification is approximately 5 times, the effective aperture or diameter of the area viewed is 0.64 or 0.32 mm, respectively. In addition an adjustable square aperture has been provided for scanning halftone prints. Two V-leaves are advanced by micrometers as is indicated schematically in Fig. 5. The large spot is approximately 1 cm in diameter and is of fixed size.

#### SCANNING MECHANISM

The simplest scanning device would be a rotating disk specimen holder. However, the scanning of halftones with the square aperture requires that the side of the square be aligned at all times with the screen direction (or its diagonal) and this is not possible with the changing screen direction of a rotating specimen.

Therefore, the design of the original instrument has been retained. The specimen is mounted on a 3/8-inch aluminum specimen holder which is driven through guides by a lead screw. The advance has been increased from the original 3.6 inches per hour to 3.6 inches per minute by replacing the worm and pinion drive by a direct friction drive. This arrangement is to be only a temporary expedient as a new mechanism providing positive drive at 3.0 inches per minute over multiple parallel scanning paths will be completed soon.

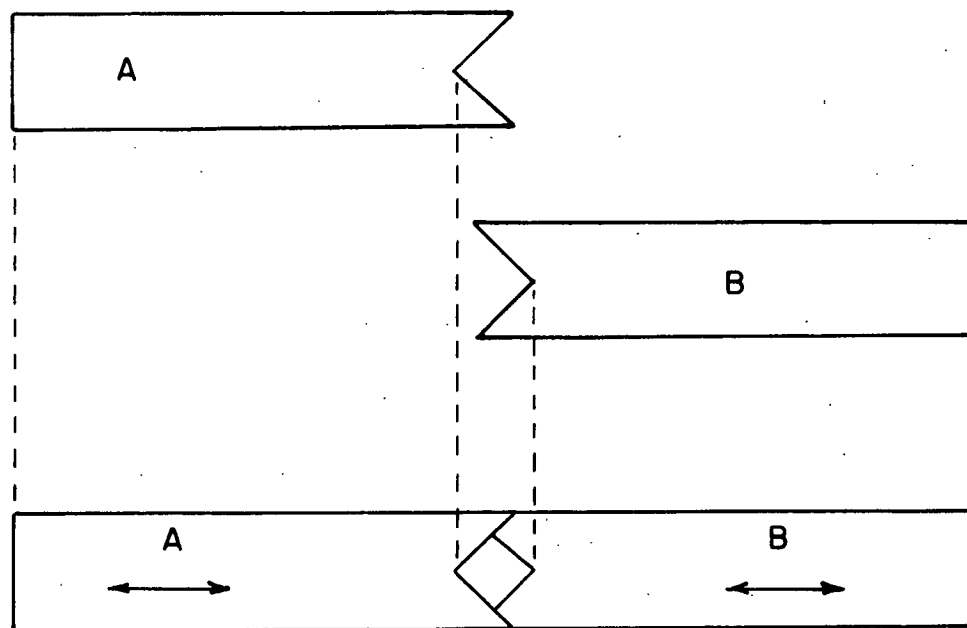


Figure 5. Schematic Diagram Showing How the Two Leaves A and B Overlap to Form a Square Aperture of Variable Size



## DISCUSSION OF PRELIMINARY RESULTS

A sample of coated board which showed a slight mottle and which had a Y reflectance of 83%, as determined on the standard brightness tester, was selected for preliminary evaluation of the instrument. Four profiles, determined along the same scanning path, are included in Fig. 6. Profile A was made with only the small aperture of 0.32 mm effective diameter and shows the very small variation in reflectance which is responsible for the noticeable mottle of this specimen. It was made at the former scanning speed of 3.6 inches per hour. Profile B was made at the same scanning speed and with the same small aperture but it is a difference profile, in which the average reflectance sensed through the large aperture (about 1 cm effective diameter) has been subtracted from the small spot reflectance and the scale of the profile expanded twenty times. The extreme sensitivity provided by the difference profile is readily apparent.

The effect of doubling the diameter of the small spot aperture to 0.64 mm may be judged by comparing profile C to B. At this larger aperture diameter much of the finer structure of the profile is lost but the major features of the pattern are retained. It will be necessary to correlate the objective measurements with subjective assessments in order to determine whether the fine structure which was lost at the larger aperture size is visually of importance. It seems probable, however, that an effective aperture as small as 0.32 mm may be unnecessary.

The effect of the sixty fold increase in scanning speed, from 3.6 inches an hour to 3.6 inches a minute (with corresponding change in recorder chart speed) can be judged by comparing profile D to B. It is superimposable on B except for a slight loss of fine detail in peaks and valleys. This small difference, which is due to the limitations of the recorder, is not believed to be significant.



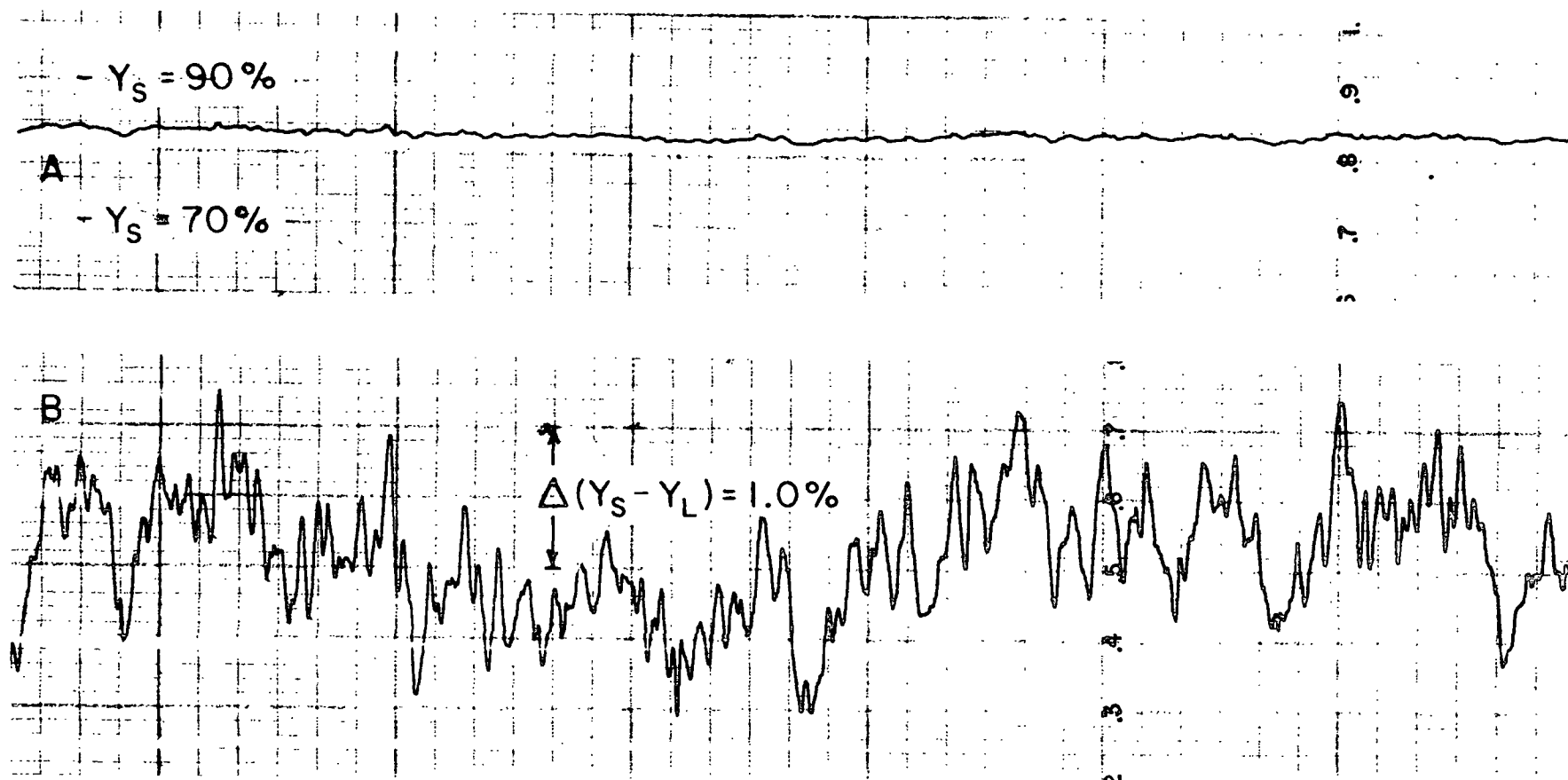


Figure 6. Four Profiles of a Coated Board Along the Same Scanning Path

A Small aperture (0.32 mm) only

B Difference profile. Small aperture 0.32 mm. Scanned at 3.6 inches/hour

C Difference profile. Small aperture 0.64 mm. Scanned at 3.6 inches/hour

D Difference profile. Small aperture 0.32 mm. Scanned at 3.6 inches/minute

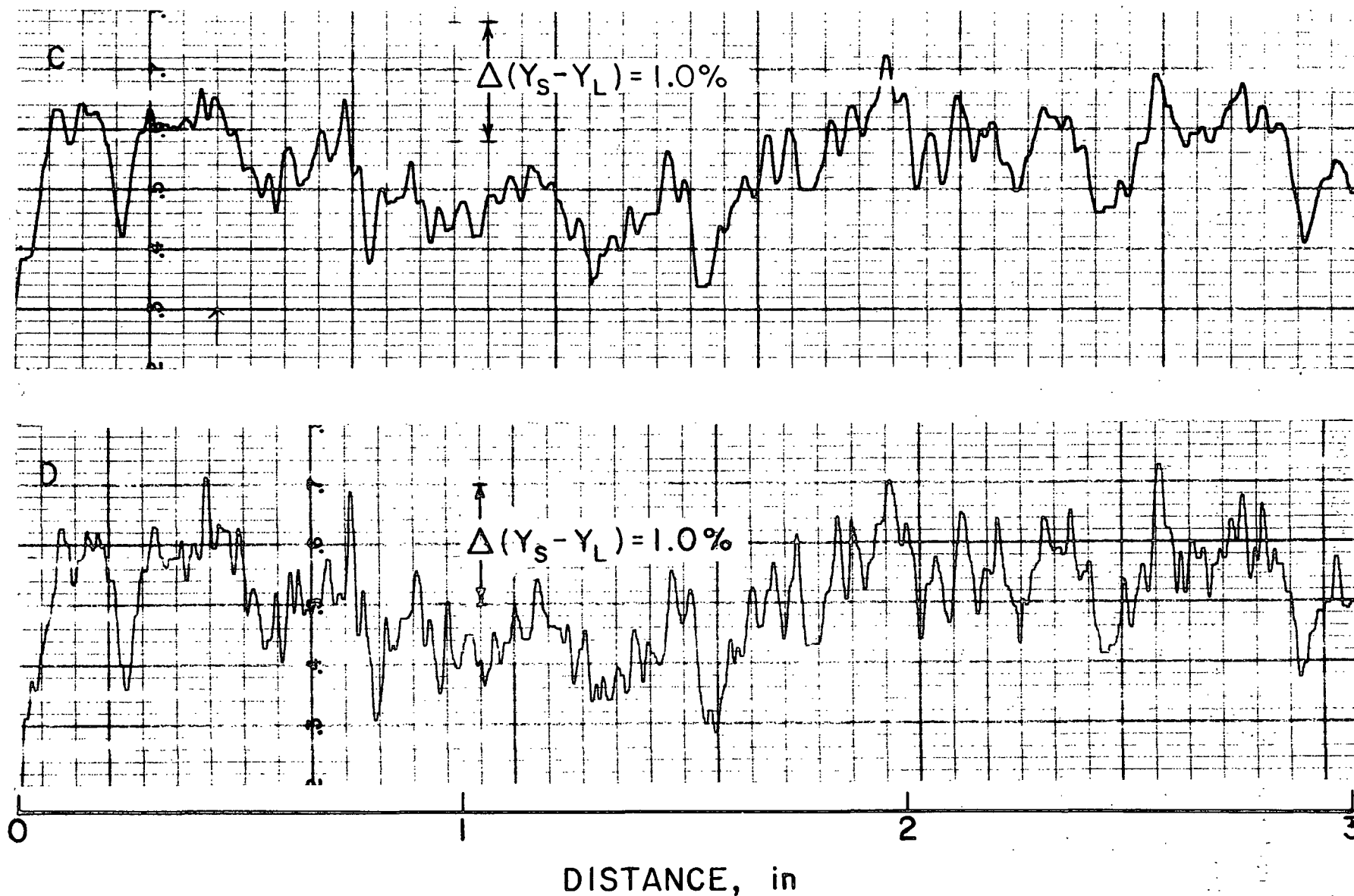


Figure 6 (Continued). Four Profiles of a Coated Board Along the Same Scanning Path

#### FUTURE WORK

Continued work will include the use of the square aperture for scanning halftone tints and gravure tones. The scanning mechanism is being modified to permit a better sampling of the area of the test specimen by closely spaced parallel scanning paths. The output of the instrument will be recorded on magnetic tape for subsequent digitizing so the computer can be used to calculate various unevenness parameters. The correlation of these objective unevenness parameters with ratings of judging panels will comprise an important part of the program, because the purpose of the project is the development of means for prediction of visual unevenness judgments.

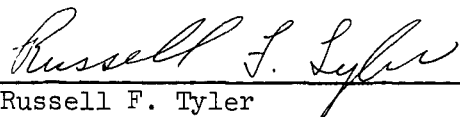
#### ACKNOWLEDGMENTS


The assistance of Mr. Robert N. Larsen of the Institute staff is gratefully acknowledged. Mr. Larsen not only designed and constructed the amplifier system but also assisted when other instrumental problems arose. Thanks are also due to Mr. Leonard Dearth and Mr. Wayne Shillcox for assistance in adjusting the spectral sensitivity of the instrument.

LITERATURE CITED

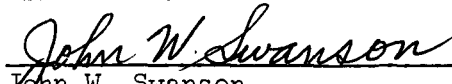
1. Leekley, R. M. and Tyler, R. F., TAPPI 6th Graphic Arts Conference Preprints 1969:41-3. Tappi 58(3):124-7(1975).
2. Ekman, H., Johansson, P. A., and Larsson, L. D., TAPPI Fall Coating and Graphic Arts Division Week Preprint 1975:163-75.
3. Ullman, U., and Qvarnstrom, I., TAPPI Fall Coating and Graphic Arts Division Week Preprint 1975:123-32.
4. Poulter, S. R. C., Tappi 51(8):87A-91A(1968).
5. Karttunen, S. The influence of paper and printing conditions upon the unevenness of prints. Thesis, 1968, The State Institute for Technical Research, Finland.
6. Bauer, G. T., TAPPI Fall Coating and Graphic Arts Division Preprint 1975:93-9.
7. Diehl, H., Int. Bull. for Printing and Allied Trades 80:20-4(1958).
8. Makkonen, T. and Nordman, L., Paper and Timber 50:509-16(1968).  
Nordman, L. and Makkonen, T., Proceedings of the Tenth International Conference of Printing Research Institutes (Krems, Austria) 1969:271-82, Pergamon Press 1971.
9. Newhall, S. M., Nickerson, D. and Judd, D. B. J. Opt. Soc. Am. 33(7):417 (1943).
10. Pobborovsky, I., Pearson, M. and Yule, J. A. C. Inter-Society Color Council, Conference on Optimum Reproduction of Color (Williamsburg, VA) 1971:161.
11. Wyszecski, G. and Wright, H., J. Opt. Soc. Am. 55:1166(1965).
12. Blokhuis, G. and Blogg, A. E., Proceedings of the Twelfth International Conference of Printing Research Institutes (Versailles, France) 1973:53-60, IPC Science and Technology Press, London, 1974.  
Blokhuis, G., Thirteenth International Conference of Printing Research Institutes (Wildhaus, Switzerland), Preprinted Paper, May, 1975.  
Blokhuis, G. and Kalff, P. J., TAPPI Fall Coating and Graphic Arts Division Preprint 1975:101-7.
13. Sankey, C. A. and Foss, L. E., Pulp Paper Mag. Can. 62:T519-31(1961).
14. Dearth, L. R., personal communication, 1975.

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\_\_\_\_\_  
Russell F. Tyler  
Research Fellow

  
\_\_\_\_\_  
Robert M. Leekley  
Senior Research Associate

Approved by

  
\_\_\_\_\_  
John W. Swanson  
Director  
Division of Natural  
Materials & Systems



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